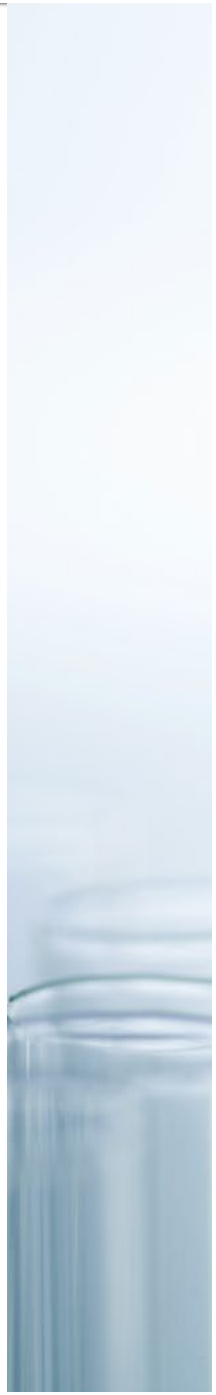


06.1 R&D at Abengoa

Achieving sustainable growth poses a number of major technological challenges that Abengoa has been successfully tackling with R&D-based solutions in the fields of energy and the environment.

Key figures	2012	2013	2014	Chg. 14-13 (%)
Patents applied for (aggregate)	200	261	312	19.5
Number of Doctors	49	85	92	8.2

R&D as a growth driver for Abengoa

Technological development has historically been the main driver of social and economic progress and this has become even more so in recent times. Large companies that have remained at the top of their game over the years have proprietary technology based on R&D to thank for their success.

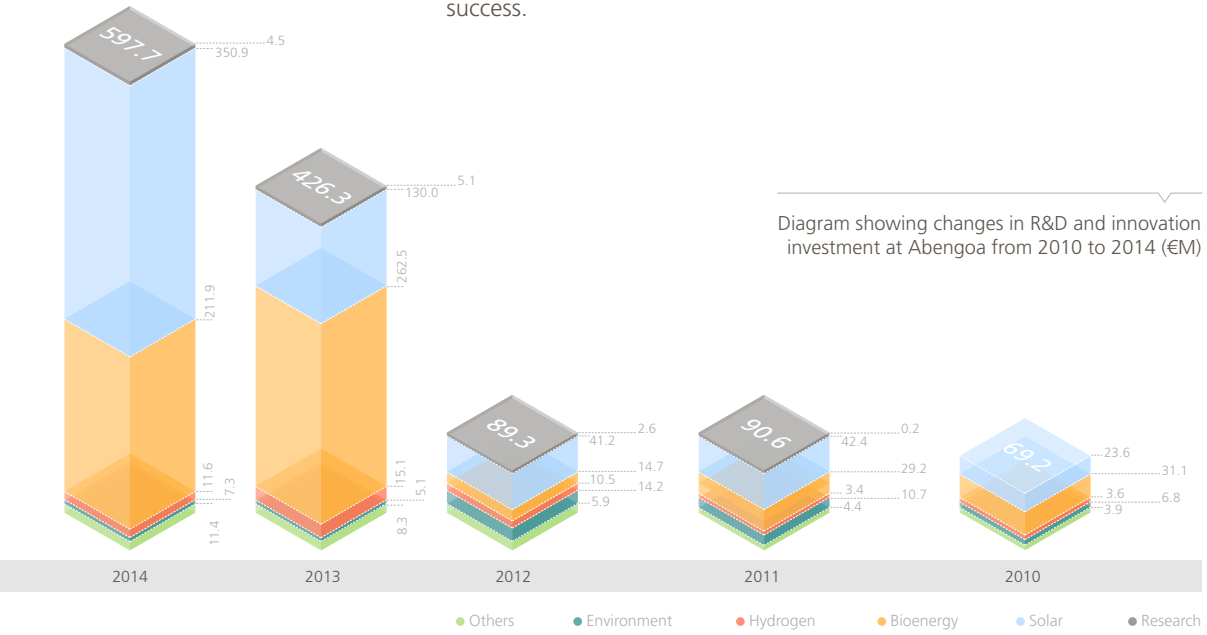


Diagram showing changes in R&D and innovation investment at Abengoa from 2010 to 2014 (€M)

At Abengoa, R&D is geared towards generating technology solutions that champion sustainable development in the fields in which the company operates: energy and the environment. R&D is therefore key to ensuring the company remains a leader in generating new products, processes and methodologies aimed at providing innovative and environmentally-friendly solutions that generate long-term value.

In a bid to enhance its R&D structure and embed it further across the entire company, Abengoa remodeled its internal R&D management and development structure over the course of 2014. R&D activity is now centralized in Abengoa Research; a new model that fosters technological and business leadership and actively drives the company towards this goal.

These recent changes underscore Abengoa's commitment to becoming an international benchmark in R&D and in generating knowledge and applying it to energy and sustainable development as a driver of the company's technological strategy.

Abengoa researches and develops projects in the following areas:

- Solar thermal electricity
- Photovoltaic energy
- Chemical processes
- Biotechnology and bioproducts
- Power systems
- Hydrogen
- Water desalination, treatment and reuse.
- Energy crops

Abengoa's R&D and innovation investment for 2014 stood at € 597.7 M, 40 % up year on year and accounting for roughly 8.1 % of sales revenue.

Abengoa successfully set up a number of **new research laboratories at the company's Campus Palmas Altas headquarters** in 2014. Research at the new laboratories is focused on new materials, power systems, chemical and heat processes and biotechnology. The facilities span an impressive 2,150 m^2 and also feature a high-performance simulation and computing center, and cutting-edge software and equipment.

Key projects in 2014

Described below are the main research projects being undertaken in the different areas:

Solar thermal electricity

Thermal and thermochemical storage

Abengoa strives to develop technologies and new lines of research that help reduce costs, boost efficiency and improve the way its solar power plants are managed. In relation to plant management, the company has developed numerous market-ready thermal storage technologies that allow electrical power to be fed into the grid day and night. These include:

- **Indirect storage based on molten salts** (Solana plant): the system employs a heat exchanger to transfer the heat energy from the thermal fluid that absorbs the concentrated solar radiation (hot oil) to the molten salts.
- **Direct storage based on molten salts** (Atacama 1 plant): the molten salts absorb the concentrated solar radiation directly.
- **Steam accumulator** (PS10, PS20 and Khi Solar One plants): a thermally insulated pressure tank containing hot water and steam under pressure.

Work is ongoing to improve these storage systems and apply them to other areas:

- **Thermochemical storage:** solar energy is stored as chemical energy through a reversible chemical process, to be subsequently released on demand by reversing the chemical reaction. Examples of research lines on which the company is currently working include partially reduced oxides, hydrogen absorption/desorption and solar fuel synthesis.
- **Thermal storage:** both as latent heat at constant temperature (also known as phase transition heat) and as sensible heat at variable temperatures without changes occurring in the physical state. In both cases, research focuses on new materials and fluids that will enable us to enhance existing technologies by storing and releasing energy at higher temperatures and/or increasing energy density per cubic meter of storage system.
- **Energy grid storage services:** Abengoa harnesses all its knowledge in researching direct grid storage services, thus helping to meet power demands at peak times while bringing power generation in line with the demand curve. This allows us to valorize and safely integrate excess electrical power coming from renewable energies within the grid, among other sources.

Photovoltaic energy

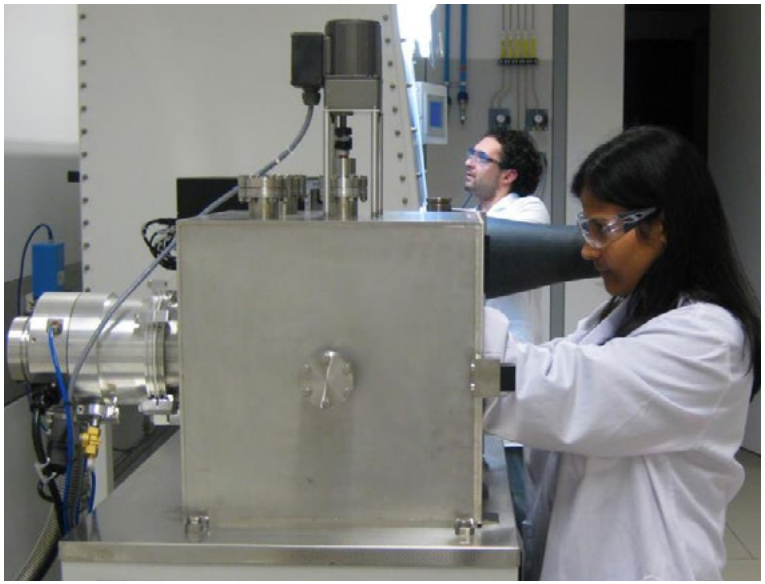
Perovskite solar cells

Abengoa is working to optimize materials and to improve our understanding of the kinetics of devices that will enable us to improve our energy conversion efficiency even further. To this end, it is working closely with institutions and universities such as the Swiss Federal Institute of Technology in Lausanne, the Max Planck Institute for Polymer Research and the University of Castilla-La Mancha.

The company has also been focusing its efforts on developing perovskite solar cells since the technology first emerged in 2012. Perovskites are **materials with extraordinary properties and are currently taking the photovoltaics sector by storm**. Their light to power conversion efficiency currently exceeds 20 %, making them hugely competitive when compared with other existing photovoltaic technologies. The total thickness of the device is less than 1 micron. This keeps material usage to a minimum and provides an excellent price-efficiency trade-off.

Perovskite has fast become a very popular choice as a semiconductor in the production of photovoltaic devices thanks to its impressive light absorption properties. Another attractive application is to make multi-layer devices featuring other available photovoltaic technologies.

It is therefore a highly promising technology with great potential to reduce costs and raise efficiency; one that might well revolutionize the photovoltaics market due to its efficiency and scope of application.



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1.
Material optimization in the production of perovskite solar cells

2.
Solar simulator for measuring photovoltaic cells

Abengoa laboratories

Chemical processes and water treatment

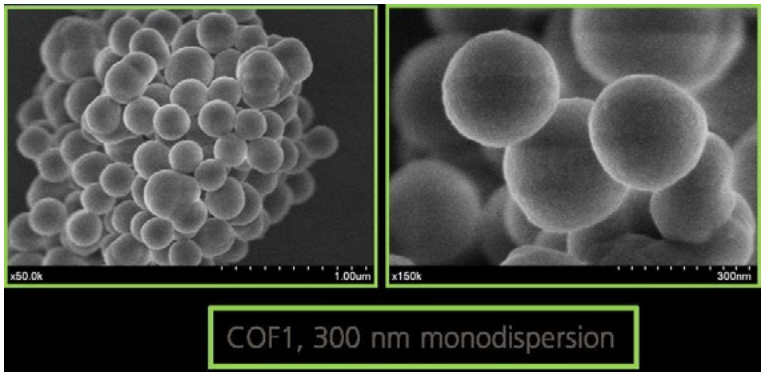
Nanotechnology applied to water treatment processes

Scientific advances in nanotechnology are creating huge opportunities to develop efficient, cheap and environmentally sustainable water treatment and desalination processes.

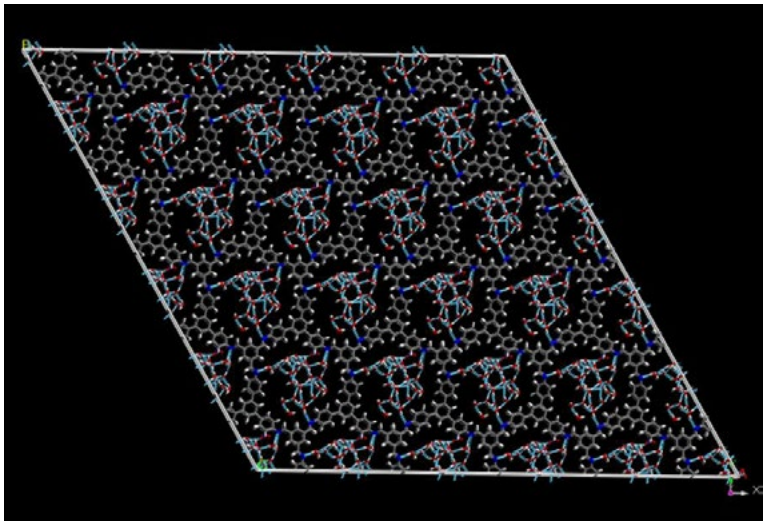
Nanomaterials offer **massive potential for resolving or at least working towards many of the existing problems associated with water quality**, with examples including nanoabsorbers, nanocatalysts, bioactive nanoparticles, and nanostructured catalytic membranes, among others.

The Nano4water project brings together a team of researchers in material physics and organic chemistry along with chemical process and water engineers from both Abengoa and collaborating entities, all working jointly to develop and offer new nanomaterials for water treatment applications.

For example, the company is working with Imdea Nanociencia and the Autonomous University of Madrid on a new family of materials known as porous covalent organic framework (COF). These can easily be rendered useful in a variety of different forms, yielding a wide and interesting range of different properties such as magnetism and hydrophilicity.



COF 1 sphere, monodispersed at 300 nm



Ab initio calculations of the interaction between a two-dimensional (2D) sheet of Covalent Organic Framework 1 (COF1) and H_2O molecules. The hydrophobicity of the COF can be observed, while the pores (2.1 nm in diameter) present a more hydrophilic response given the interaction with the amino groups of the COF

Biotechnology and bioproducts

Enzymes for generating biofuels from municipal solid waste (waste to biofuels, W2B) and from agricultural residue or biomass (2G)

The acronym "Cambios" comes from Combined Approaches Based on Metagenomics for Biofuel Synthesis, a metagenomic project being spearheaded by Abengoa's Biotechnology Division.

Metagenomics is the scientific study of all the genomes present in a given environment recovered directly from environmental sampling without the need to isolate or grow the organisms present in the environment.

The project aims to explore the biodiversity of the ungrowable microbial world **in search of enzymes that could prove useful in biofuel synthesis**. To focus the search, the Biotechnology Division flags those niches that could play host to the desired enzymatic activities. From there, it can seek out enzymes capable of degrading lignocellulosic material (bottleneck in the production of second-generation bioethanol) by exploring the existing biodiversity present in goat rumen.

The project also encompasses a number of tasks aimed at overcoming the intrinsic difficulties posed by metagenomics, such as detecting elusive enzymatic activities or designing a versatile microorganism with which to scrutinize these enzymatic activities.

With this project, Abengoa is bidding to develop a raft of powerful molecular tools to continue leading the second-generation biofuels sector and transform municipal waste into liquid fuels.

Power systems

Smart Solar Plant (SSP)

Abengoa is working to develop smart solar power plants that combine **photovoltaic and solar thermal technologies with thermal and electrochemical storage to ensure the best possible integration within the electric power system**. In addition to generating clean energy at a cheaper tariff, these plants will be able to provide power grid support services to help optimize their position in competitive electricity markets.

The SSP project embraces the design and implementation of a smart distributed control system that pursues three key objectives:

- Increasing automation in the control of integrated power generation plants.
- Providing the SSP with advanced functionalities when interacting with the power grid to improve grid performance.
- Extending the intelligence of the SSP control system towards the modern energy and services markets.

The project also involves developing equipment, such as the virtually synchronous power converters, along with other facets concerning information analysis (big data), control algorithms and distributed control system architectures. It also analyzes the impact this new kind of plant will have on a number of key locations, such as California, Chile, South Africa and Germany.

Hydrogen

Electrocatalysis

Redox reactions cover a multitude of processes occurring daily in nature that involve chemical reactions generating an exchange of electrons between different species.

These electrons can be exchanged in a controlled environment using an electrochemical cell operating at well-established intensities and voltages. An electrocatalytic reaction occurs when the electrode not only transports the electrons but also has a catalytic function. Electrocatalysis has acquired enormous importance in the race to develop fields such as organic electrosynthesis, sensors, fuel cells and batteries.

Abengoa has developed and patented its own proprietary electrocatalytic technology in collaboration with the University of Castilla-La Mancha with the aim of:

- **Producing hydrogen and syngas simultaneously**, with a suitable H_2/CO ratio to improve and optimize the final application of the product (fuels, chemical products, and so on).
- **Valorizing CO_2** to improve the cost efficiency of plants that generate this greenhouse gas and thus transform it into useful products (methane, methanol, etc.) by using the H+ generated from the water electrolysis as a hydrogen source.
- Causing the electrooxidation of organic molecules **to generate high purity hydrogen**.

Energy crops

Biomass for biofuels

Energy crops are used to generate biomass for conversion into power. The aim is to ensure that the plants are highly adaptable in a production sense, generating low costs for both growth and harvesting.

Abengoa's research focuses on **maximizing biomass production** in as short a time as possible. To this end, various lines of research have been rolled out **to increase plant energy potential through agronomic and biotechnological techniques**.

The key objectives here are to establish the conditions in which the best tree growth rate can be achieved - a biological parameter that changes depending on species, age and growing conditions (soil, crop density, hours of light and available water, among others) - along with the maximum possible planting density, and to define the ideal conditions for ensuring the best possible energy return on energy invested. The company is also exploring the best growing conditions so as to improve the growth of trees while avoiding any negative impact on soil quality.

New laboratories of investigation
in Campus Palmas Altas, Seville (Spain)